ix. Cryogenic Control System

A stand alone process control system is required for the Cryogenic System. When desired this will permit operation of the Cryogenic System independent of the main RHIC control system. This may occur quite frequently during periods of cooldown and warmup. The refrigerator and compressor control sub-system was designed, installed and in operation since 1984. It originally consisted of 3 PDP11® computers and Crisp® software running the refrigerator and compressors via an input/output (I/O) system. The I/O system interfaces a total of about 1700 points consisting of analog and digital input/output points, temperatures and PID loops. Through these points, the I/O system controls the cryogenic vacuum system, purifiers, compressors, refrigerator and gas management.

To make the refrigerator responsive to changing conditions, the turbine expanders can be operated in "cascade" mode. In this mode, the output of a proportional+integral+derivative (PID) controller, monitoring liquid helium pot level or system temperature, becomes the speed setpoint for the expander or first expander in a turbine expander train. The speed setpoint for the second expander in a train is slaved to the speed of the first.

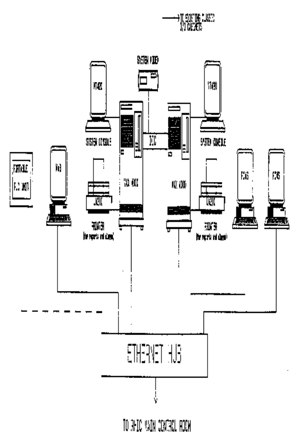

Fig. 3-7. Cryogenic Control Room

The new Cryogenic Control System design which also includes the Ring Control Sub-System, replaces the three PDP11® computers with two VAX® 4000/400 computers connected in a hot back-up configuration (Fig. 3-7). The old I/O system and an updated version of the Crisp® Process Control Software are both useable on the new system. Included in the new design are three 20" color operator workstations running Crisp® Process Control Software. Any workstation can be used to generate or modify databases and programs or perform other functions such as historical trending and analysis and creating reports from the Crisp® system database.

One of the most powerful tools of Crisp® software is the graphic system which provides the opportunity to create and modify standard and custom process graphic displays on-line without any programming required. Thus, hundreds of pages of graphic display of all cryogenic variables can be generated and linked to the database on the fly, without a glitch or interruption of operation of the process control system.

The dual VAX® computers are connected in a hot-backup configuration. While only one computer is in control, the other one is always updated of the activity of the first one. If the active computer fails, the inter computer communications (ICC) network (Fig. 3-7) which connects the two VAX® together automatically switches control to the backup computer. Since the backup system was continuously updated, the transition is totally smooth with no loss of information and no human intervention.

The Ring Control Sub-System consists of a programmable logic controller (PLC), one at each of the six experimental areas. They are connected to the cryogenic control room via the RHIC Controls network shown in Fig. 3-8. The ethernet hub in the cryogenic control room (Fig. 3-8) is attached to the fiber distributed data interface (FDDI®) concentrator in the RHIC Control Room via the router/bridge. Communication between the RHIC Control Room and each of the six experimental areas is done via single mode fiber optic cables in the star configuration. At each experimental area, the PLC processor manages all cryogenic signals via input/output (I/O) modules located in crates distributed along the RHIC tunnel, connected to the PLC via a local data highway running at a speed of 250 kbaud as shown in Fig. 3-9. There are about 3000 points around the ring to be monitored and controlled for a system total (including refrigerator and compressors) of almost 5000 points.

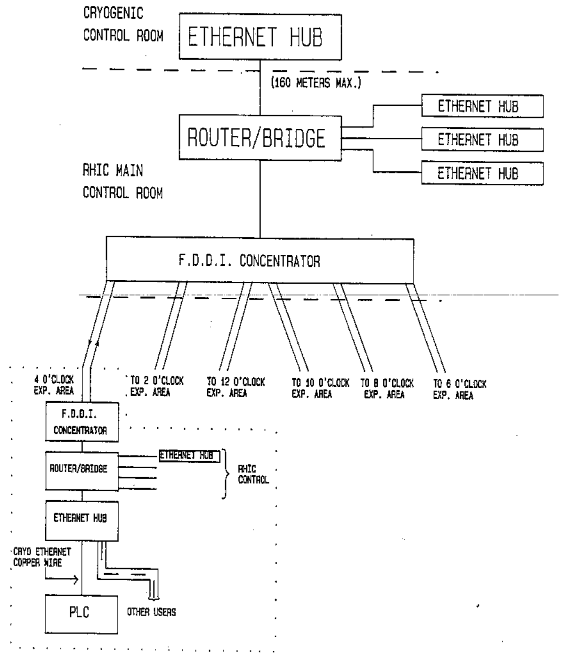

Fig. 3-8. Routing of Cryogenic ethernet over RHIC controls network.

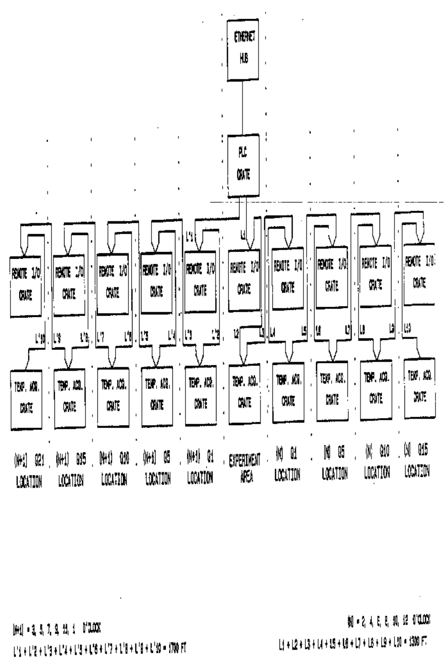

Fig. 3-9. Local control distribution.

The ring remote I/O crate consists of a 19 inch rack mountable chassis with its own power supply, I/O scanner and as many I/O modules as needed. Some of the points to be controlled are: Mass flow controllers (MFC) used to control the flow of helium gas which cools the superconducting magnet power leads. The MFC are located at the room temperature end of the power leads. Magnet current is read by the PLC via analog input module in the remote I/O crate. A control program stored in the PLC sets the control point of the MFC for a prescribed flow of helium. Flow readback from the MFC is sent back to the PLC via analog input module to verify proper operation. If the MFC fails to open, a digital command signal is sent to open a solenoid valve across the MFC, thus by-passing it.

The PLC is also programmed to control the helium liquid level in the recooler at a fixed level. This is achieved by reading the liquid level via analog input module and positioning the opening of the valve via analog output module to keep the liquid level constant.

The rest of the cryogenic signals controlled by the PLC via the I/O crates are pressure sensors and low level flow indicators using thermistor resistors in the self-heating mode and cooled by the flow of helium gas.

The ring temperature acquisition crate[1] consists of a 19 inch rack mountable EUROCARD® chassis located in the same cabinet as the remote I/O crate. It is an in house designed multiplexed data acquisition system with an overall accuracy of ± 20 PPM, which translates into a temperature accuracy reading of less than 1mK for temperatures below 10 K. The system reads temperature of pre-calibrated transducers such as germanium, silicon diode, thermistor or platinum temperature sensors. It ships the results (digitized analog reading) to the PLC via the local data highway. There, the raw data is linearized by use of corresponding polynomial coefficients and finally shipped to the main computer database via the RHIC Controls network.

[1] Y. Farah, J. H. Sondericker, "A Precision Cryogenic Temperature Data Acquisition System", Advances in Cryogenic Engineering. Vol. 31 (Plenum Press, New York, 1985).

In the design of this system, a clear choice was made in favor of using many remote I/O crates (up to a maximum of 32) distributed along two tunnel sectors, thus minimizing the length of cables between transducers (points) and the electronics. This choice was driven by the low cost of the remote I/O crates in comparison to the cost of fire-retardant cables.

The PLC software is developed at the PC workstation in the Cryogenic Control room. A portable PLC unit complete with a remote I/O and temperature acquisition crates is attached to the PC workstation via the ethernet hub (Fig. 3-7). This unit located next to the workstation is used to test the PLC software. Once the software is bug free, it is downloaded to the individual PLC in the experimental areas via the RHIC Controls network.

Communication between the CRISP® database in the VAX® computers and the PLC is done via CRISP® intelligent device interface (IDI) over the RHIC Controls network.

Finally, the calibrated temperature transducer coefficients are shipped from the calibration room to the individual PLC via BNL network.

The state of the cryogenic system is needed for the operation of some of the components of the collider such as the power supply and the vacuum systems. Therefore, a communication link between the cryogenic and RHIC main computers is necessary. On the cryogenic side, a directory is created under VMS® operating system in which an ASCII input/output file is written. This file will contain all the necessary data to be shared between the two computers over the RHIC controls network. Under VMS® authorize utility, access to variables in the directory by either the main or cryogenic control systems is limited to predetermined status, control and interlock functions.